Solenoid Spectrometer Project

Status Report

A. H. Wuosmaa

Centennial
1903·2003 Celebration

WESTERN MICHIGAN UNIVERSITY

Department of Physics
College of Arts and Sciences

What’s it all about?

- New spectrometer to study light particles from inverse-kinematic reactions

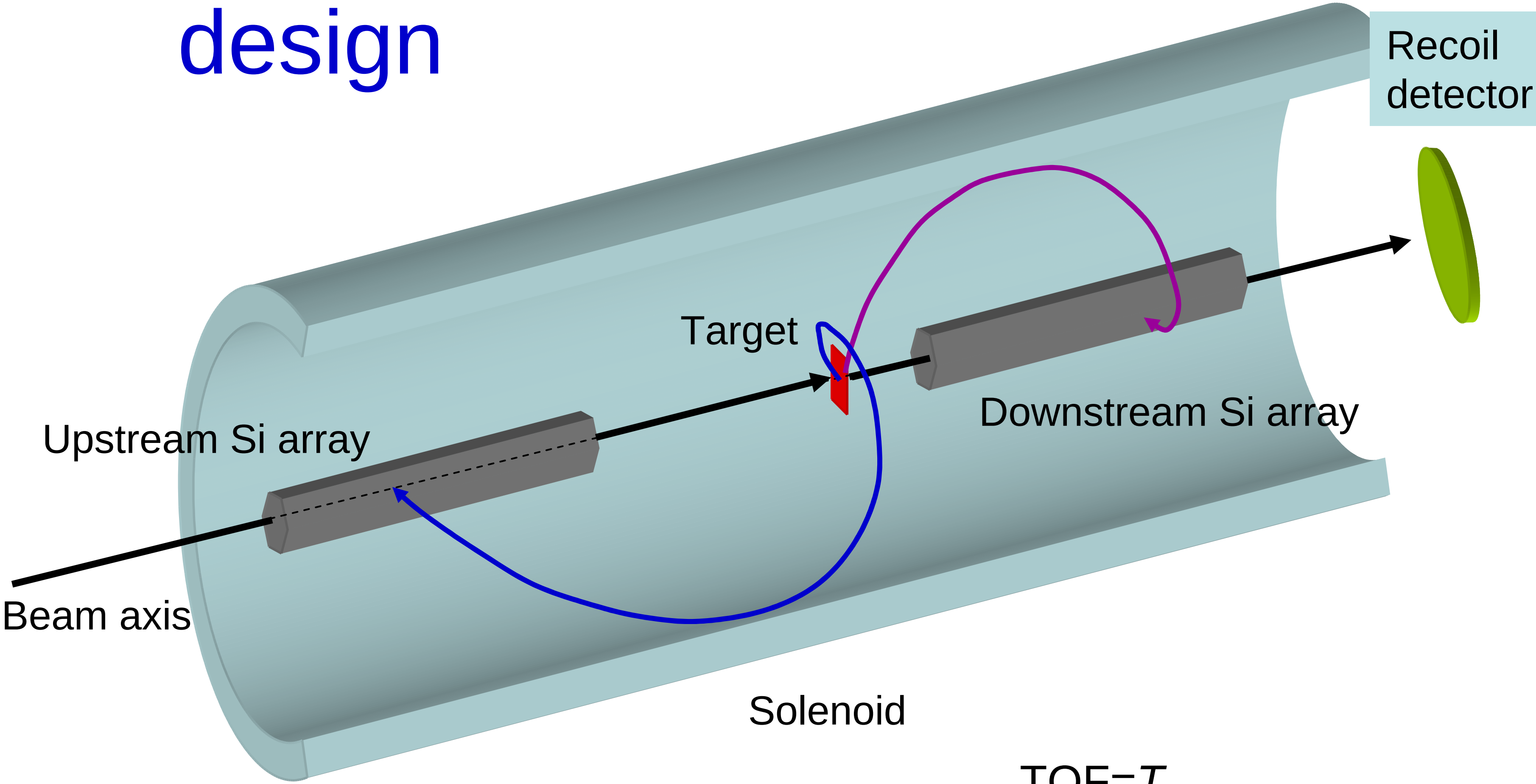
Physics Needs:

- Nucleon transfer reactions with unstable beams
  - (d,p), (d,^{3}He), (α,t), (^{3}He,α), etc.
  - Other reactions that produce low-energy light charged particles are possible
- Nuclear structure
- Nuclear astrophysics
- Stockpile stewardship

Why a new device?

- Challenges:
  - Achieve large acceptance
  - Particle identification at low energies
  - Center-of-mass energy resolution
  - Kinematic shifts and multi-valued kinematics
  - Background suppression
- Present devices may not be ideal when contending with some of these issues

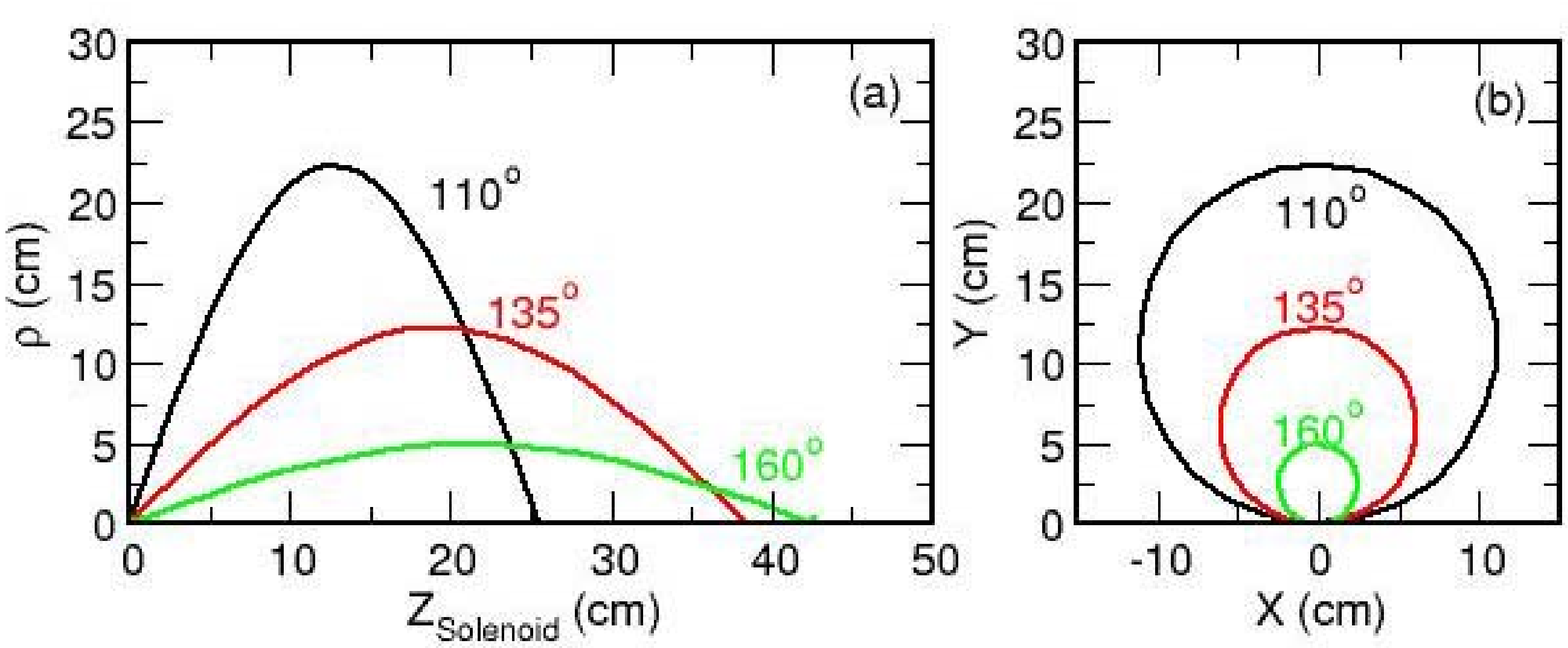
Conceptual design



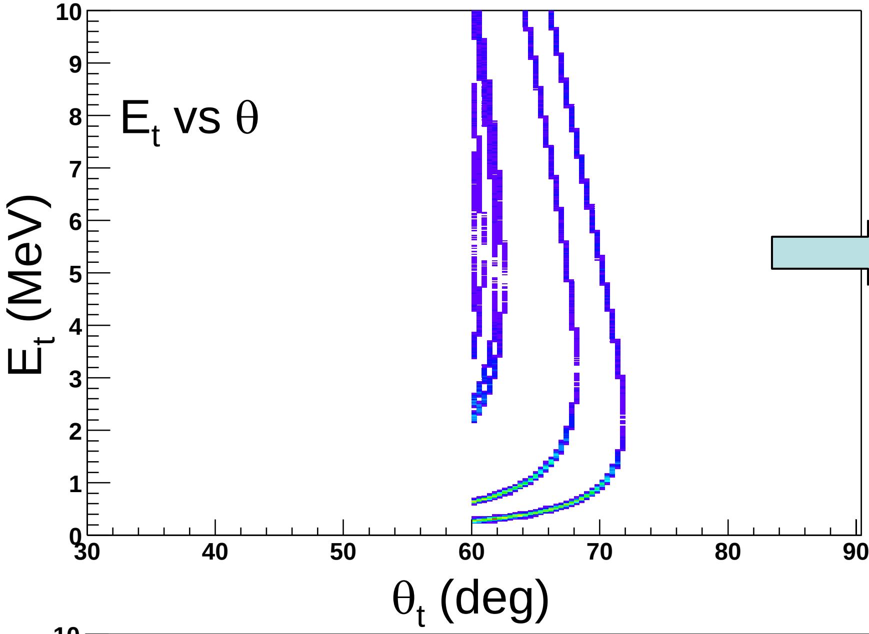
TOF=T_{CYC}
Gives m/Q (Particle ID)
T_{CYC}~10s of ns

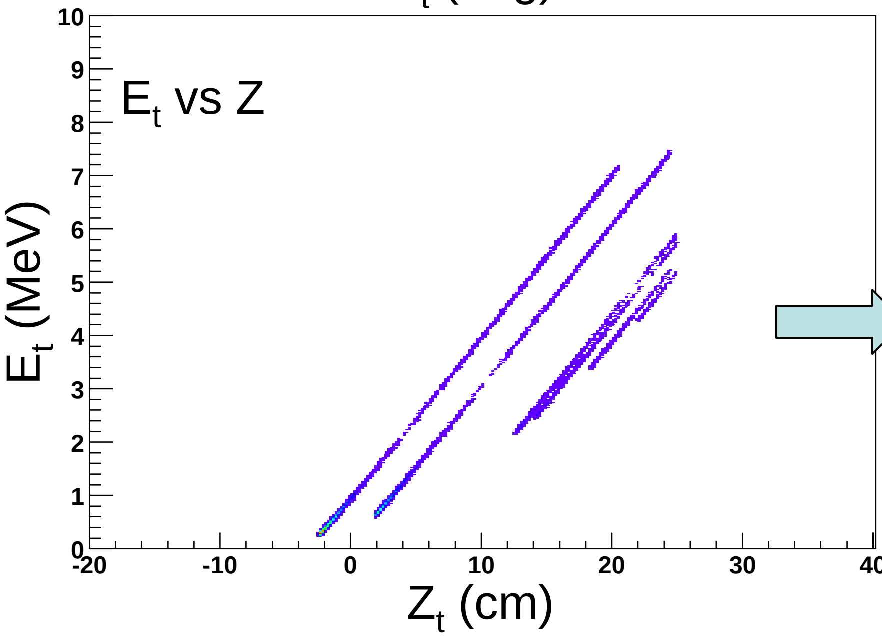
Proton trajectories for d(^{132}Sn,p)^{133}Sn$_{g.s.}$

E(^{132}Sn)=8 MeV/u
B = 2.36 T

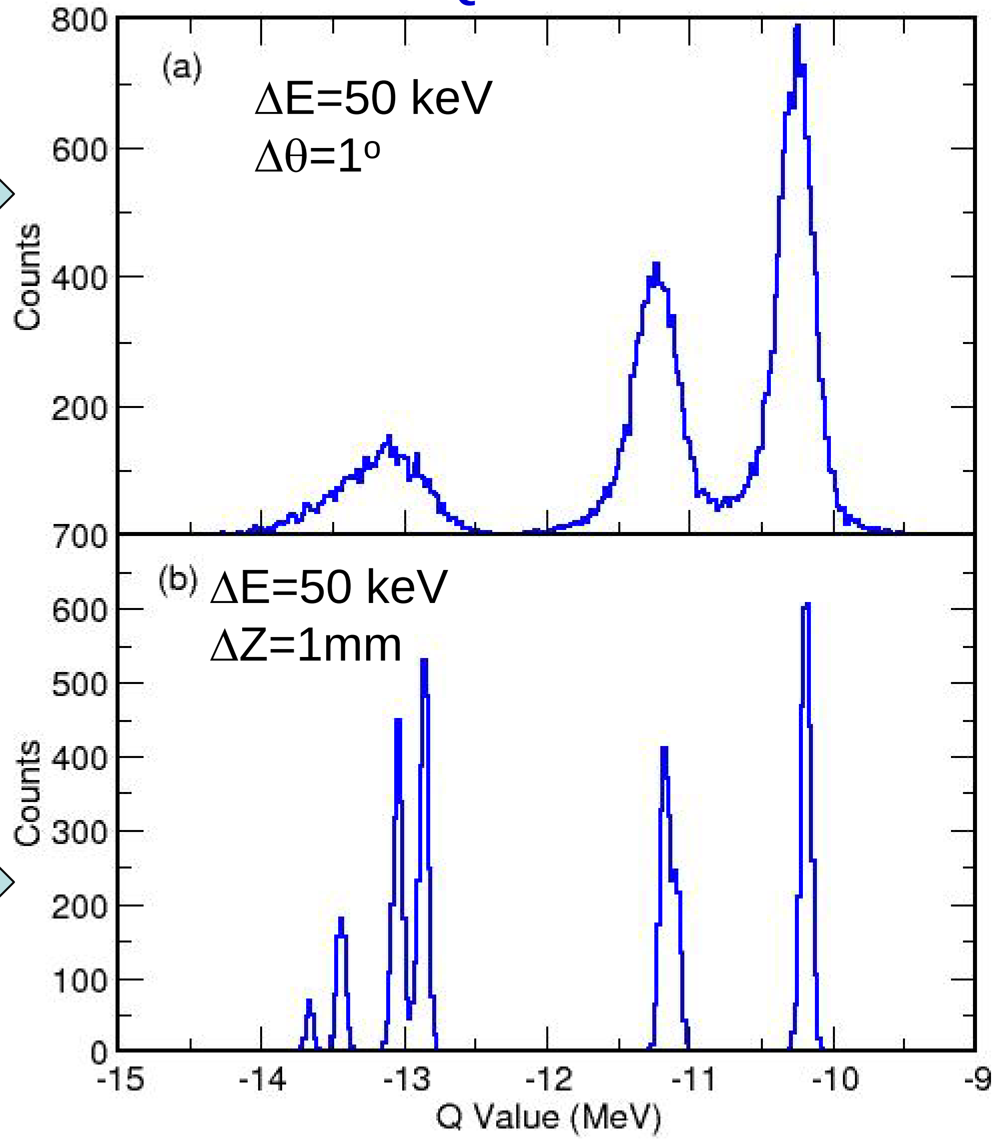


Improved resolution for $^{132}Sn(\alpha,t)$





Q Value



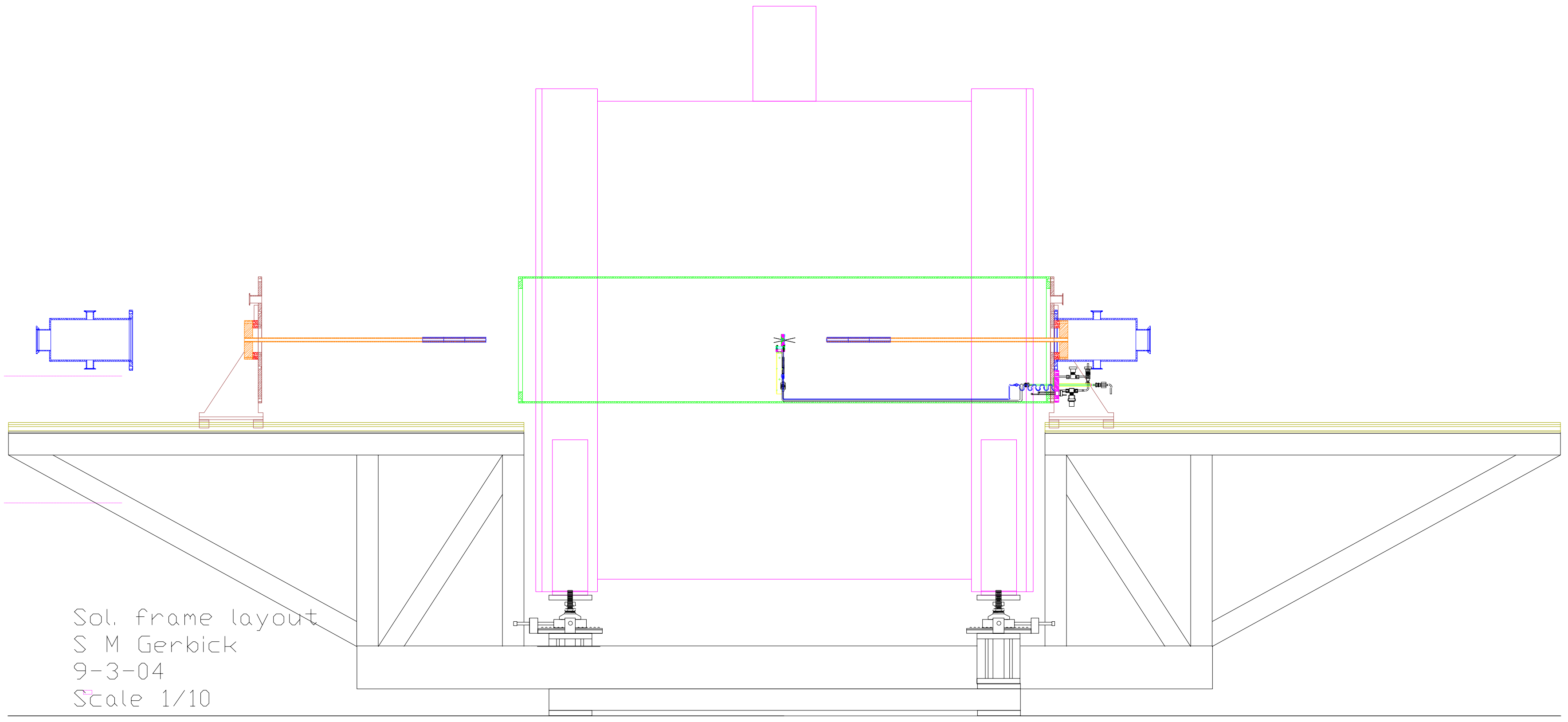
Advantages and disadvantages

- 👍 Suppression of background
- 👍 Simple Particle ID
- 👍 Clarification of kinematics (excited states are separated in position as well as energy)
- 👍 High efficiency ($\Omega \sim 2\pi$)
- 👍 Simple detector (few segments)
- 👎 Need a large superconducting solenoid (~$500k, concerns with large stray fields)
- 👎 Target, detector, other mechanics more challenging

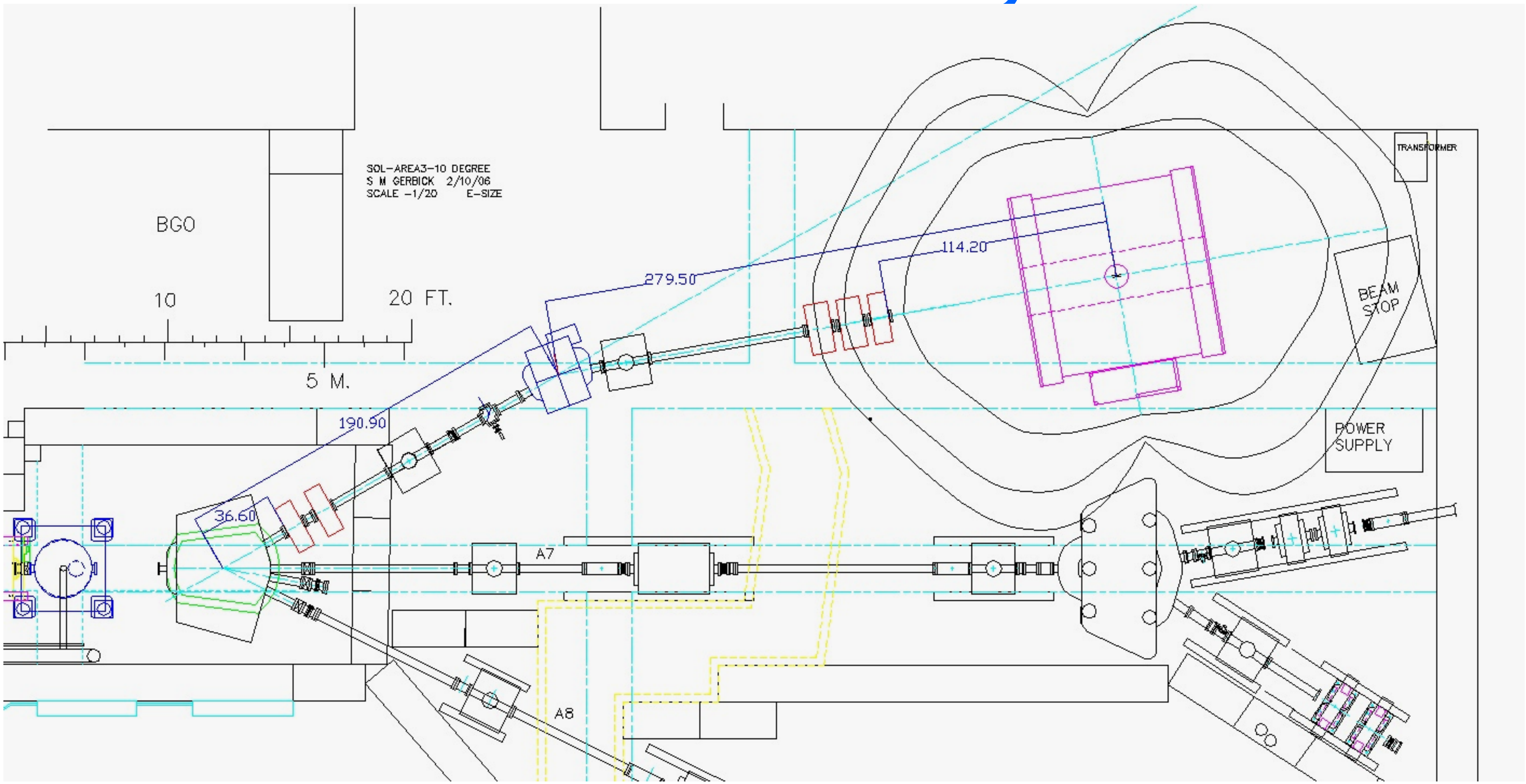
Timeline

- Presentation of idea at RIA equipment workshops at LBNL(1998), ORNL (March 2003)
- June 2004 Workshop on Inverse Kinematics at ANL
- October 2004, Proposal Submitted to DOE
  - (available on the ATLAS web page)
- A resounding silence.
- In 2005, LDRD funds at ANL became available for design work, feasibility studies, some procurement
- New budget projections for FY07
- Funds available for construction??!!

Magnet layout



GP area floor layout



Accepts stable, In-flight, and CARIBU beams

Status

- LDRD money for detector array available for electronics – some purchasing underway
- Silicon for prototype array exists and is tested (~50 1 cm X 5 cm PSD sensors)
- Floor plan exists for GP area (move existing beam line to adjacent magnet port)
- Budget projections look good for construction in Calendar 07/08
- The search for a good acronym continues…

WHO (working group)

- ANL:
  - B. B. Back (ANL Project Manager)
  - C. J. Lister
  - R. C. Pardo
  - K. E. Rehm
  - J. P. Schiffer
- WMU
  - AHW
- Manchester
  - S. J. Freeman (recoil detectors)

Also contributions from many others too numerous to name!

Cyclotron period for different particles (B=2T)

Particle	T(Cyclotron)
p	32.8 ns
d	65.6 ns
t	98.4 ns
^{3}He	49.2 ns
^{4}He	65.6 ns

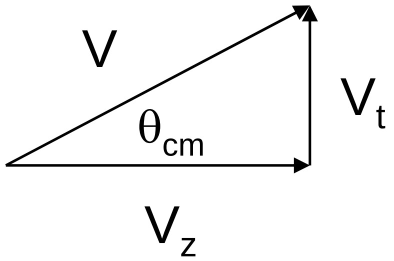
$$T(cyc) = \frac{2\pi m}{qB}$$

T(cyc) is <u>independent</u> of energy and angle!

Why it works

- Solenoid spectrometer disperses in $V_{||}$ (velocity parallel to beam)
- $V_{||}$ in Lab are related to $V_{||}$ in C.M. by a simple boost.
- For a given detector, the differences in particle energies in the lab are equal to the differences in the C.M.
- No degradation in C.M. energy resolution from kinematics

Why it works…

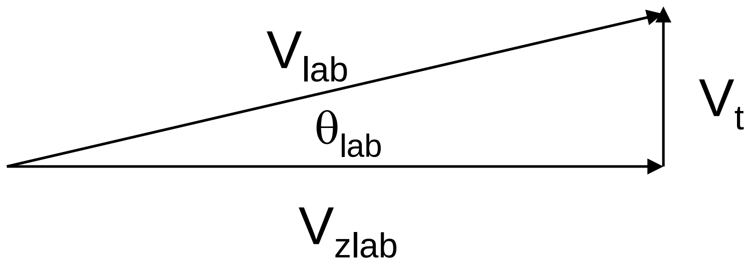


$V_z = V\cos\theta_{cm}$

$V_t = V\ \sin\theta_{cm}$

$V \sim (E_{c.m.} + Q - E_x)^{1/2}$

Center of mass



$V_{zlab} = V_z + V_{CM}$

$V_{tlab} = V_t$

$E_{lab} \sim V_{lab}^2 = V^2 + V_{CM}^2 + 2V_z V_{CM}$

Laboratory

Since: $T = T_{cyc}$, if two groups arrive at the same Z,

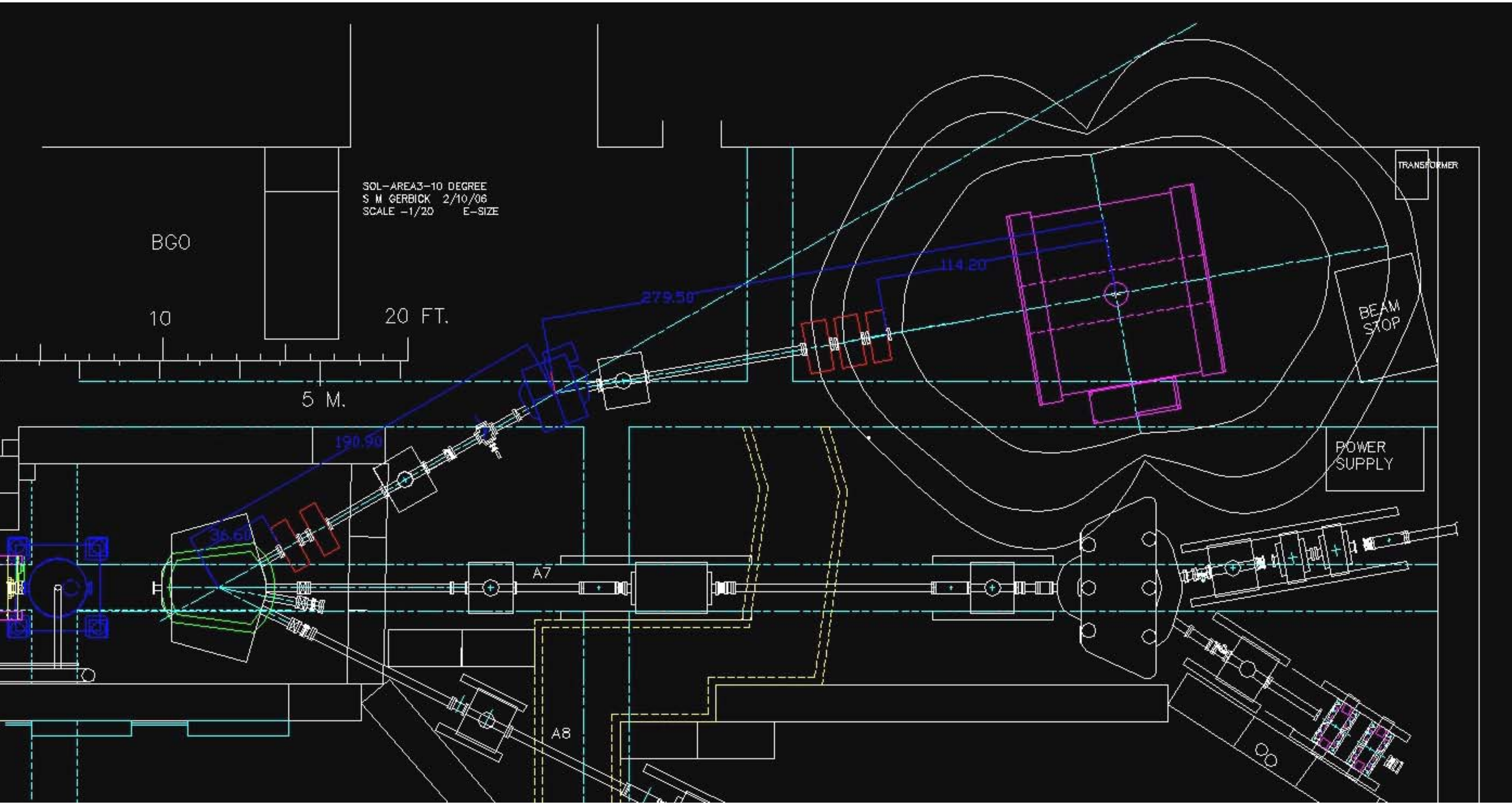
then $V_{zlab1} = V_{zlab2}$ and $V_{Z2} = V_{Z1}$

$$\Delta E_{lab} \sim V_{2lab}^2 - V_{1lab}^2 = (V_2^2 + V_{CM}^2 + 2V_{Z2}V_{CM}) - (V_1^2 + V_{CM}^2 + 2V_{Z1}V_{CM})$$

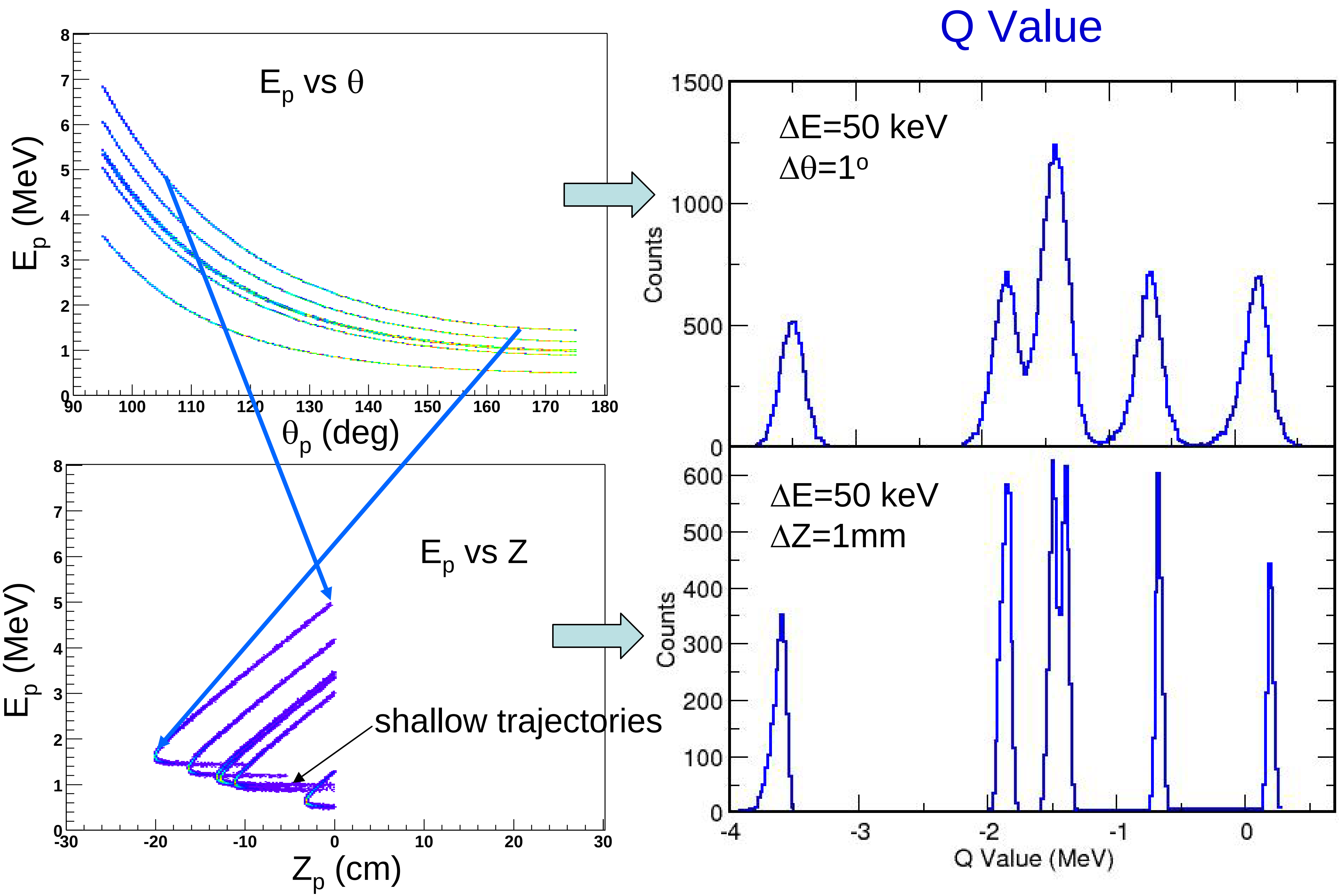
$$= (V_2^2 - V_1^{2)} + 2V_{CM}(V_{Z2} - V_{Z1})$$

But $V_{z2} = V_{z1}$! So: $\Delta E_{lab} = V_2^2 - V_1^2 \sim E_{X1} - E_{X2}$!

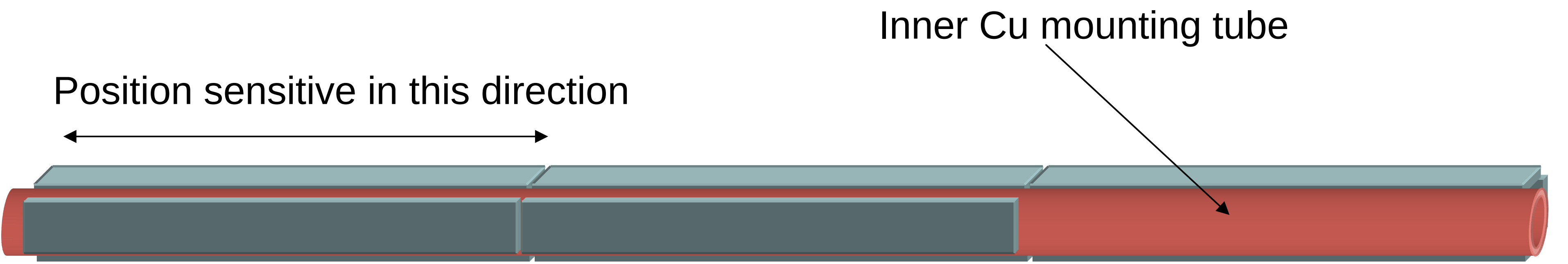
GP area floor layout



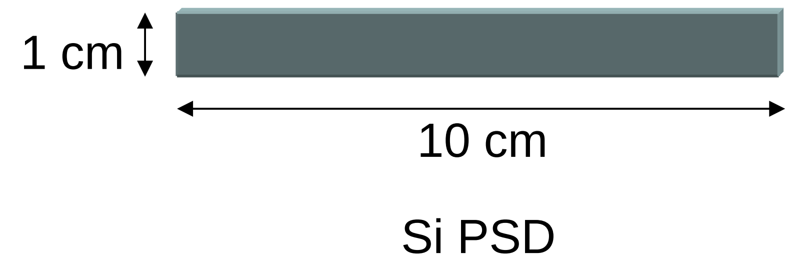
Improved resolution for (d,p)



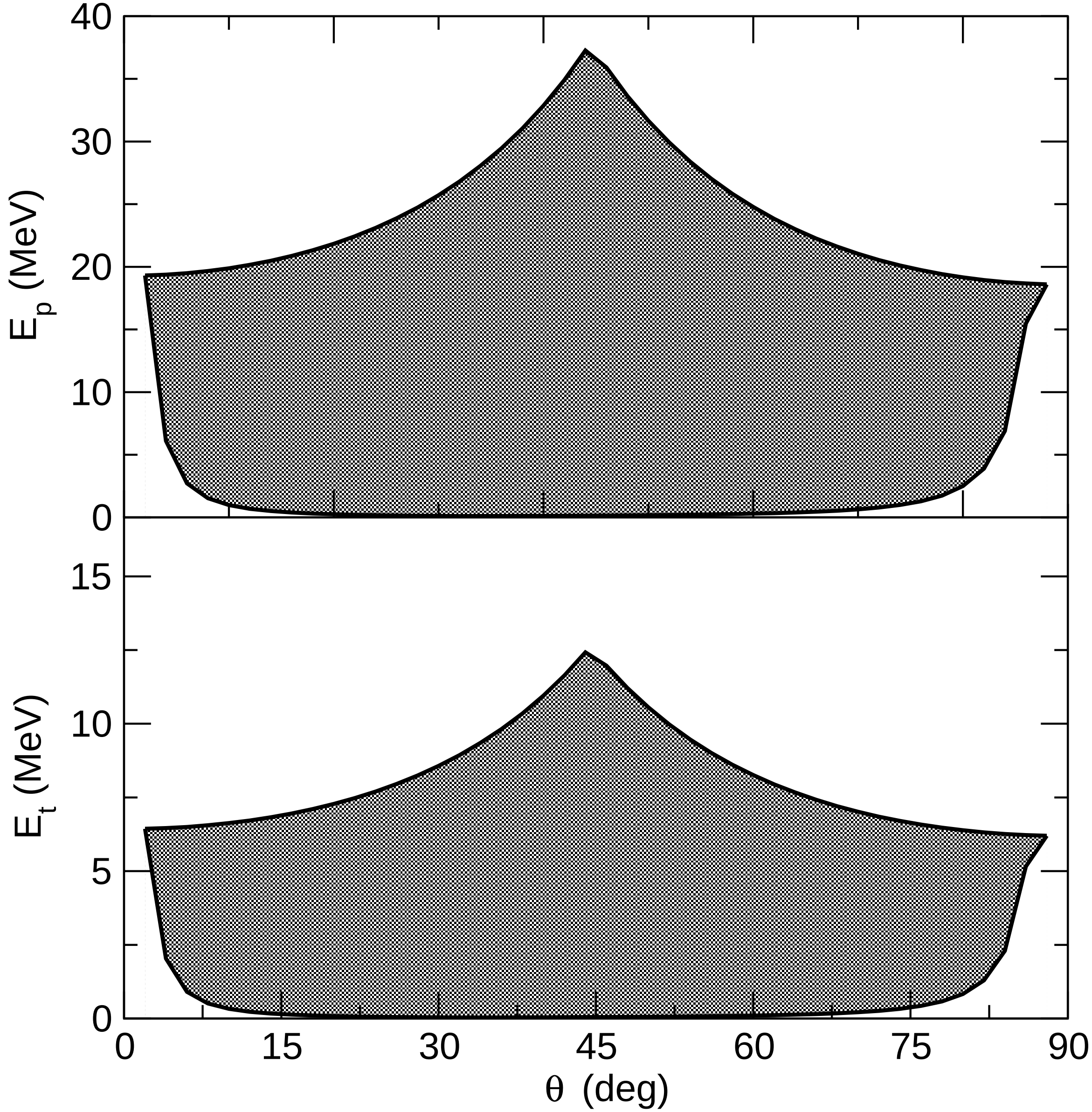
Silicon array schematic design



Two arrays:



12 Si PSD elements each
Total length 30 cm
Inner tube must accommodate beam, recoils
Could be Cu to permit cooling
Challenges: signal and bias connections
mechanical support
minimize gaps in structure
make cross section as small as possible

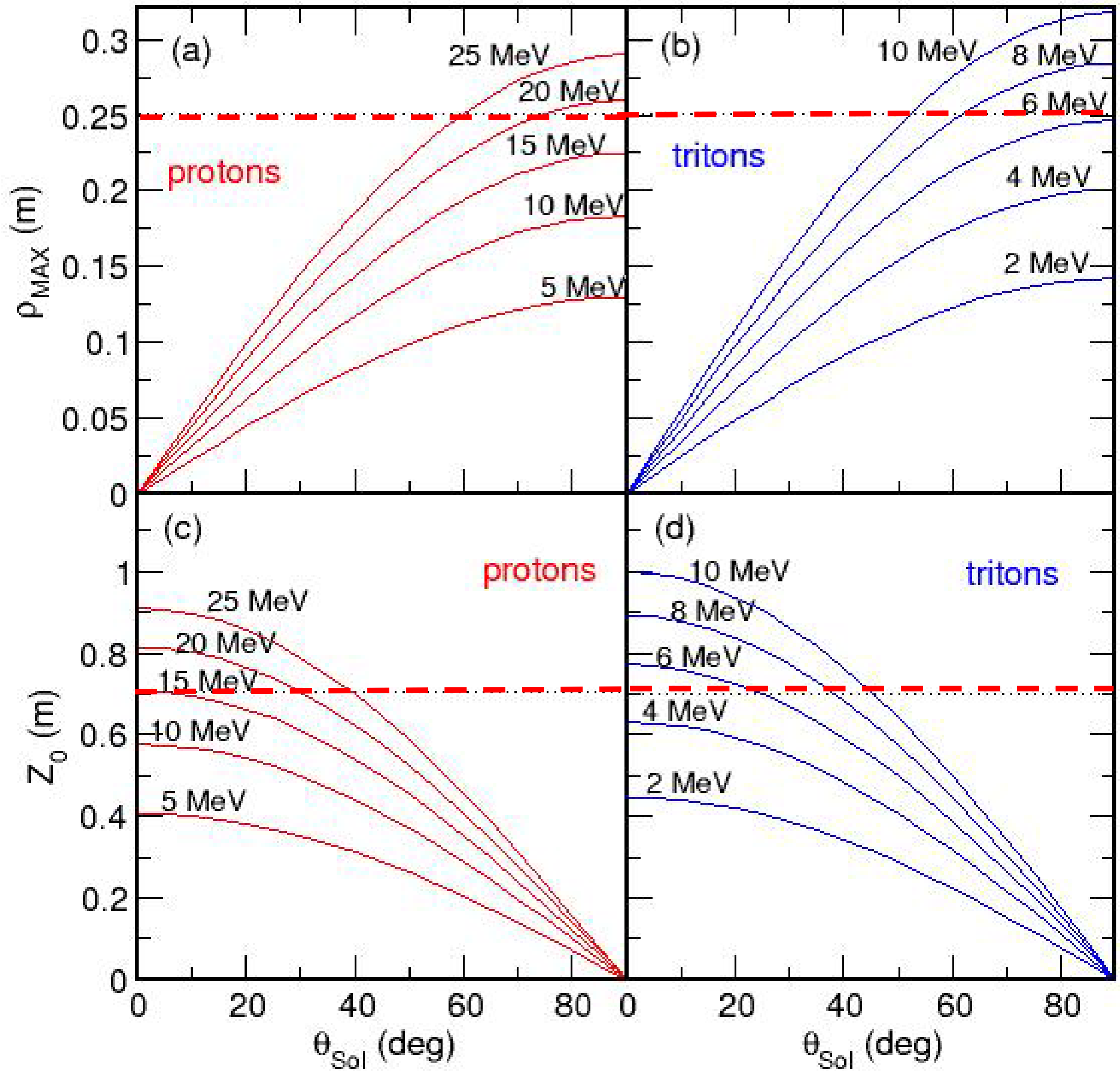


40
30
20
10
0
E_p (MeV)
15
10
5
0
E_t (MeV)
0
15
30
45
60
75
90
θ (deg)

Physics Needs

- Nucleon transfer reactions with unstable beams in inverse kinematics
  - (d,p), (d,^{3}He), (α,t), (^{3}He,α), etc.
  - Other reactions that produce low-energy light charged particles are possible
- Nuclear structure
- Nuclear astrophysics
- Stockpile stewardship

Solenoid Acceptance with B=5 Tesla



Limit imposed by 25 cm solenoid radius

Limit imposed by 75 cm solenoid half-length